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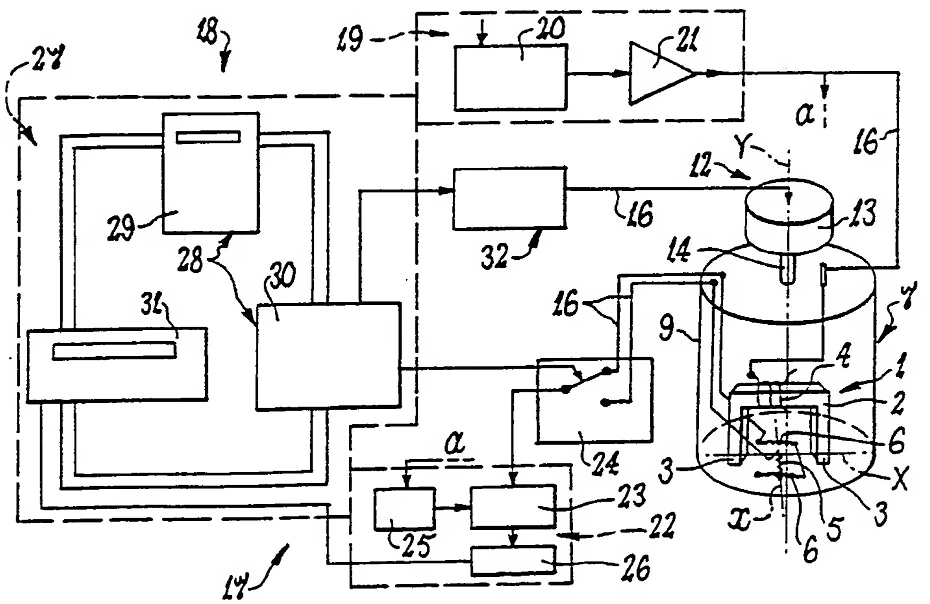
(54) Title: NON-DESTRUCTIVE DETERMINATION OF STRESS CHARACTERISTICS IN MAGNETIC MATERIALS

(57) Abstract



An instrument (17) for determining one or more stress characteristics within a surface layer of magnetisable material. Instrument (17) includes probe (7) having a carrier (8) rotatable about a rotation axis (Y) extending perpendicularly outwardly from a magnetisable material surface (M). An electromagnet (1) is mounted on t he carrier (8) and provides a pair of poles (3) spaced apart, one on either side of the rotation axis, on a pole axis (X) so that on carrier rotation the poles (3) circulate about the rotation axis (Y). The electromagnet (1) is energisable to produce a magnetic field (H) between the poles (3). A search coil (5) is fixed relative to the electromagnet (1) between the poles (3), on an axis (x) so as to lie in the magnetic field (H). Drive means (12) is operable to rotate the carrier (8) to selected angular positions. The probe (7) is positioned with the poles (3) adjacent the material surface (M) so that the magnetic field (H) extends into the surface, shifts in the magnetic field (H) caused by stress in the material surface (M) inducing representative voltages in the search coil (5) at the angular positions. Instrument (17) also includes control apparatus (18) for controlling operation of the drive means (12) and, at each selected angular position of the carrier (8) for receiving parameters from the probe (7) for determining the stress characteristics.

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NON-DESTRUCTIVE DETERMINATION OF STRESS CHARACTERISTICS IN MAGNETIC MATERIALS

This invention relates generally to the non-destructive measurement of stress within a surface layer of magnetisable materials, and in particular to a probe for providing at least one parameter used in determining one or more stress characteristics within the surface layer of magnetisable materials as well as an instrument including the probe for determining magnitude and direction characteristics of such stress. The probe and instrument are applicable for determining magnitude and direction characteristics of residual stress in the surface layer of steel railway wheels, and it will be convenient to hereinafter describe the invention in relation to that exemplary application. It is to be appreciated, however, that the probe and instrument are not limited to that application.

During manufacture, railway wheels are heat treated in order to leave the wheel rim, including the surface layer, in residual compressive stress in a circumferential direction. In this way, any cracks developing in the rim surface layer while the wheel is in service, particularly in the tread region, tend to close up under influence of the compressive stress.

However, in service, the wheel may heat up sufficiently that the rim yields. This may particularly occur during wheel braking where brake shoes are applied directly to the wheel tread. Then, upon cooling the rim, including the surface layer, may be left with residual tensile stresses in the circumferential direction. Such stresses would tend to open

cracks in the wheel rim, with the potential to cause wheel failure.

A variety of non-destructive techniques and equipment have been developed for periodically checking this residual stress while the wheels are in service, in an effort to anticipate and avoid wheel failure.

One simple procedure involves applying a coat of paint to the wheel rim surface and monitoring that paint during a period of wheel use for any visible color changes indicative of variations in stress. This technique is inaccurate and thus unreliable.

Equipment has also been developed which uses a measurement of the Barkhausen Noise as a basis for rejecting wheels exhibiting dangerously high circumferential tensile stress in railway wheels. However, that equipment is very expensive, and its accuracy and effectiveness are not fully proven.

It is an object of the present invention to provide a relatively simple probe that can be used to determine one or more stress characteristics within the surface layer of magnetisable materials.

It is another object of the present invention to provide a relative simple and accurate instrument for determining magnitude and direction characteristics of stresses in magnetisable materials.

A further object of the present invention is to provide an instrument for determining magnitude and direction of residual stresses in the surface layer of steel railway wheels in order to detect destructive stresses in those wheels and

thereby alleviate possible in service wheel failure.

With these objects in mind, the present invention broadly provides a probe and an instrument including the probe that can be used for determining specific stress characteristics in the surface layer of magnetisable materials using, as a basis, the known effect that stress has on the magnetisation of those materials. Stress, either residual or applied can make steel anisotropic. At moderate magnetic fields, the permeability of mild steel is highest in the direction of tensile stress and lowest perpendicular thereto. When magnetised in a direction between those maximum and minimum permeabilities, the directions of magnetic field and magnetic flux density relatively shift so as to angularly differ depending on the difference in two relatively generally perpendicular principal stresses in the surface layer of the material. The instrument uses this effect to determine the characteristics of difference between the principal stresses (principal stress difference) as well as the direction of those stresses. (stress direction). In the exemplary application those principal stress are the radial and circumferential stresses in the surface layer of a railway wheel rim.

According to one aspect of the present invention there is provided a probe for providing at least one parameter used in determining one or more stress characteristics within thesurface layer of magnetisable material, including: a carrier rotatable about a rotation axis extending perpendicularly outwardly from a magnetisable material surface; an electromagnet mounted on the carrier and providing

a pair of poles spaced apart, one on either side of the rotation axis, on a pole axis extending parallel to the material surface so that on carrier rotation the poles circulate about the rotation axis, the electromagnet being energisable to produce a magnetic field between the poles; a search coil fixed relative to the electromagnet between the poles, on an axis extending parallel to the material surface and perpendicular to the pole axis, so as to lie in the magnetic field; and, drive means operable to rotate the carrier to selected angular positions, the probe in use being positioned with the poles adjacent the material surface so that the magnetic field extends into the surface, shifts in the magnetic field caused by stress in the material surface inducing representative voltages in the search coil at the angular positions.

The present invention, in another aspect provides an instrument for determining one or more stress characteristics within the surface layer of magnetizable material, including: the above probe; and, control apparatus for controlling operation of the drive means rotating the carrier and, at each selected angular position of the carrier, for receiving the parameter(s) from the probe for determining the one or more stress characteristics.

In one embodiment, the drive means includes an electric drive motor having a rotary output shaft connected to the carrier for rotation thereof. That drive motor is a stepper motor in one embodiment.

In one embodiment, the electromagnet includes a C-shaped magnet core having the poles at terminal ends thereof and an

exciting coil wound about the core.

The search coil is a wire wound air cored coil positioned mid way between the poles in one embodiment of the probe and instrument.

In one embodiment, at least one reference coil is fixed relative to the electromagnet between the poles, on a respective axis extending parallel to the pole axis, so as to lie in the magnetic field. In use of the probe, the magnetic field produced between the poles induces voltages in the reference coil(s) representative of the magnetic field. A pair of reference coils may be provided one adjacent each end of the search coil and in a plane common with the search coil. The reference coils may be each wire wound air cored coils.

The probe also includes in one embodiment, a housing having an opening and a bearing surface adjacent the opening. The carrier is positioned in this housing with the poles and search coil exposed through the opening. In this way the probe is positioned with the bearing surface abutting the material surface and the poles and search coil facing through the opening to the material surface.

The control apparatus in one embodiment of the instrument includes a power supply device for providing exciting power to the electromagnet. That supply device may include a fixed frequency and amplitude oscillator for generating sinusoidal alternating current power supply and a power amplifier for receiving the power supply from the oscillator and supplying the power to the electromagnet.

The control apparatus includes in one embodiment a

signal process for processing induced voltages in the search coil. That signal processor may include one or more voltage filters.

In one embodiment the control apparatus includes a control computer for controlling operation of the drive motor and compiling voltage parameters from the search coil. That control apparatus may include a display device for visually displaying the parameter values from the probe as derived values thereof.

The following description refers to preferred embodiments of the probe and instrument of the present invention. To facilitate an understanding of the invention, reference is made in the description to the accompanying drawings where the probe and instrument are illustrated in preferred embodiments. It is to be understood that the invention is not limited to the preferred embodiments as hereinafter described and illustrated in the drawings.

In the drawings:

Fig. 1 is a schematic front elevation of part of the probe according to a preferred embodiment of the present invention;

Fig. 2 is a schematic plan view of part of the probe of Fig. 1;

Fig. 3 is a schematic plan view of part of the probe, similar to Fig. 2 but showing various angles associated with a magnetic field and flux density produced by the probe part in use;

Fig. 4 is a graphic representation of induced voltage versus angle of rotation as occuring during use of the probe

part;

Fig. 5 is a graphic representation similar to Fig. 4 but after induced voltage filtering and rectification;

Fig. 6 is a side elevation, in partial section, of the probe according to a preferred embodiment of the present invention;

Fig. 7 is a diagramatic view of the instrument according to a preferred embodiment of the present invention, incorporating the probe of Fig. 6;

Fig. 8 is a calibration curve graph for AAR M208 grade C steel (cast 0.72% carbon) for calculating principal stress difference during use of the instrument; and

Fig. 9 is a plan view showing principal stresses in the surface layer of material as determined using the instrument of the present invention.

Referring initially to Figs. 1 and 2, the principles on which the probe and instrument of the present invention are based will be briefly outlined.

These Figs. generally illustrate electromagnet 1 having C-shaped magnet core 2 made of laminated magnet material, such as Mumetal or silicon-iron laminations. Core 2 has opposite, spaced apart poles 3 arranged on pole axis X with rotation axis Y extending perpendicular therebetween. Core 2 is wound with exciting coil 4 between poles 3, with coil 4 being connectable to a source of alternating current (A.C.) power (not shown). By way of example, coil 4 is composed of 200 turns of 30 B and S wire. Current drawn by coil 4 is non-critical and, in the preferred embodiments is a few hundred milliamps at low frequencies, by way of example, about

150 mA at 68, 80 or 144 Hz.

Fixed in position between poles 3 is small air cored search coil 5. Coil 5 is carefully arranged mid way between poles 3, with its longitudinal axis x extending perpendicular to axis X. Search coil 5 is composed of as many turns of fine wire as is conveniently possible, and by way of example has 2000 turns of 48 B and S wire.

Also fixed in position between poles 3 are two small air cored reference coils 6, one located at each end of search coil 5. These coils 6 are arranged with their axes extending parallel to axis X. Coils 6 are connected in series and, as will be explained hereinafter, are useful in determining the effect, on stress sensitivity, of differing surface roughness or coating thickness of material being measured. Again, coils 6 are composed of as many turns of fine wire as is conveniently possible and, by way of example, each has 1500 turns of 48 B and S wire.

When electromagnet 1 is in air, away from magnetisable material, and power is provided to exciting coil 4, magnetic field H is set up between poles 5 inducing flux density B. Field H and density B extend generally parallel with one another, substantially straight between poles 5 as represented by lines of magnetization in Figs. 1 and 2. In consequence, no voltage V_5 is induced in search coil 5, although a voltage V_6 is induced in reference coils 6 which provides a direct measure of field H.

When electromagnet 1 is arranged with poles 3 placed against a surface (such as a steel surface) of magnetizable material M as shown in Figs. 1 and 3 then magnetic field H

extends into the surface layer and is caused to shift angle θ away from the direction of any tensile stress in that layer. In contrast, flux density B, also extending into the surface shifts toward the direction of that stress. Importantly, as a result of this angular shift a small A.C. voltage V_5 is induced in search coil 5. Moreover, if poles 3 with coils 5 and 6 are rotated about rotation axis Y then the angular shift of field H varies as does induced voltage V_5. In effect induced voltage V_5 is proportional to sin θ.

It has been experimentially established that the RMS numerical value of voltage V_5 changes approximately as a rectified sine wave with the change of angle of rotation about axis Y, as shown in Fig. 4. Voltage V_5 can be rectified electronically so that it is a positive voltage for values of rotational angles between 0° and 90° and between 180° and 270°, and a negative voltage for values of rotational angles between 90° and 180° and between 270° and 360°. This is shown in Fig. 5 where voltage V_5 has maximum values (V_5 max) at rotational angles of about 45° and 225°, and minimum values (V_5 min) at rotational angles of about 135° and 315°. Thus, complete rotation of poles 3 about axis Y will produce two maximum and two minimum values of voltage V_5 at specified angles of rotation. It is the values of voltages V_5 and V_6 and angles of rotation at which they occur that are used as parameters for determining stress characteristics in the material surface layer.

Voltage V_5 parameters will not provide actual principal stress values in the material surface layer but rather only allow derivation of the principal stress

difference. Moreover, the angles of rotation parameter will not provide a distinction between the directions of tensile and compressive stresses but experience enables that determination. Thus, in the exemplary application, an angle θ value of around 90° indicates that the circumferential stress is smaller (more compressive or less tensile) than the radial stress, while an angle θ value of around 0° or 180° indicates the circumferential stress is larger (more tensile or less compressive) than the radial stress.

The extent to which magnetic field H penetrates into material M depends at least to some extent on the level of exciting power and frequency supplied to electromagnet 1. However, with the probe of the present invention that penetration is generally only into the surface layer for determining stress characteristics in that layer. In the exemplary application the penetration is to a depth of about 1 mm.

Referring now to Fig. 6, there is generally shown probe 7 forming part of the instrument of the present invention. Probe 7 is quite portable and manually handled in use of the instrument. Probe 7 incorporates electromagnet 1, as well as search coil 5 and reference coils 6 (one only being shown for simplicity) as previously described. Electromagnet 1, and coils 5 and 6 are relatively fixed together in carrier 8 mounted in rigid probe housing 9 for rotation about axis Y. Carrier 8 is tube like in this embodiment, with open end 10, poles 3 and coils 5 and 6 being exposed through open end 10. Surrounding open end 10 is bearing face 11 of housing 9 which, in use of instrument 17, bears against a surface of material M.

Probe 7 further includes drive means 12 mounted to housing 9 and connected to carrier 8 for rotation of carrier 8 together with electromagnet 1 and coils 5 and 6. Drive means 12 includes electric drive motor 13 having rotatable output shaft 14 connected to carrier 8. In this embodiment, motor 13 is a stepper motor operable to accurately rotate shaft 14 in either direction through small angular increments, such as about 15°.

Electrical connections from exterior of probe 7 to moving exciting coil 4, search coil 5 and reference coils 6 are made through any suitable arrangement, and in this embodiment includes trailing ribbon cable 15 electrically connected to external flexible cable 16.

Now referring to Fig. 7, there is diagrammatically shown instrument 17 of the present invention, incorporating probe 7. Instrument 17 also includes control apparatus 18 for controlling operation of probe 7 and assisting in determining the stress characteristics from the parameters provided by probe 7.

Apparatus 18 is conveniently also portable for remote use of instrument 17, and is connected to probe 7 through cable 16. Apparatus 18 includes power supply device 19 for providing exciting power to coil 4. Supply device 19 includes fixed frequency oscillator 20 for supplying sinusoidal alternating current supply to power amplifier 21 which, in turn, supplies exciting coil 4. Oscillator 20 is fixed in frequency and amplitude during actual operation of instrument 17, but can be altered at will in order that instrument 17 can measure stress to different surface layer depths within

material M.

Power to oscillator 20 is provided from any suitable source, and in the exemplary application that power is conveniently sourced from batteries (not shown) to enable the instrument 17 to be portable. Those batteries are rechargable, and supply device 19 includes a battery charger (not shown) for periodically recharging the batteries from a mains power supply source in this embodiment. The batteries are 12 volt, D.C. in this embodiment.

Apparatus 18 also includes voltage signal processor device 22 for processing induced voltages V_5 and V_6 from coils 5 and 6. To that end, search coil 5 and reference coils 6 are connected to phase sensitive filter 23 through switch 24 for receiving and rectifying any voltage V_5 or V_6. Filter 23 is required because induced voltages V_5 and V_6 are very small (typically a few hundred microvolts (μV) in the exemplary application) and are thus prone to interference. Phase shifting network 25 supplies filter 23 and caters for the change in phase between magnetising current and voltages V_5 and V_6 induced in coils 5 and 6. An output voltage from filter 23, passing through zero - adjust device 26, is D.C.

Apparatus 18 further includes computing device 27 connected to processor device 22 for compiling relevant parameters from the output voltages. In particular, computing device 27 reads and displays voltages V_5 and V_6 and angle θ parameters. Computing device 27 includes a suitable control computer 28 (such as programmable calculator 29 and interface board 30), and visual display 31 (such as multimeter) for

displaying the actual parameter values and/or values derived therefrom through calculation by calculator 29. Control computer 28 controls operation of switch 24.

Apparatus 18 further includes motor control 32 interconnecting control computer 28 and drive motor 13 for selectively supplying drive power thereto. In essence control computer 26 dictates incremental movement of output shaft 14 during operation of instrument 17.

In operating instrument 17, probe 7 is initially manually placed against a surface of material M from which stress characteristics are to be determined. In the exemplary application, probe 7 is positioned so that bearing face 11 is flat against a surface of a rim of a railway wheel. Probe 7 is secured against the material surface as necessary. That is achieved in any suitable manner, such as by mechanical or magnetic clamping devices (not shown).

Upon activation, control computer 28 controls rotation of carrier 8 about axis Y, as well as the collection of numerical values of parameters, voltages V_5 and V_6 and angles of rotation about axis Y. In particular, drive motor 13 is controlled so as to rotate carrier 8 through 345^{o} at 15^{o} increments. At each angular increment, rotation of carrier 8 is temporarily stopped for a separate reading of the three parameters.

Using the numerical values of the three parameters it is then possible to determine the principal stress difference in the material surface as well as the stress direction. In the exemplary application this difference is between the radial and circumferential stresses in the wheel rim. That

determination is made with reference to relevant graphed calibration curves C prepared from laboratory measurements of stresses in samples of the same materials. Those curves C will vary according to the material being measured and may incorporate errors as a result of a stress-hysteresis effect in materials.

By way of example, a calibration curve graph for AAR M208 grade C steel (cast, 0.72% Carbon) is shown in Fig. 8. The graph contains a set of curves C, each providing a calculated measure of the principal stress difference for given voltage V_5 diff which is the algebraic difference between the average of the two maximum voltage values V_5 max and the average of the two minimum voltage values V_5 min. Separate curves C are provided for different effective air gaps formed between poles 3 and the surface of material M in use of instrument 17. The larger the effective gap, the smaller voltage V_5 diff will be for the same principal stress difference. The effective gap will increase if the material surface is corroded, as might occur in the exemplary application. The gap is detected by a change in value of voltage V_6.

Each calibration curve C is marked with a value ΔV_6 which is the difference in voltage between the voltage values of V_6 as induced on the material surface and V_6 as induced in the ambient air. Since voltage V_6 values change slightly with ambient temperature as well as with the effective air gap, use of voltage ΔV_6 rather than just voltage V_6 as induced on the material surface means that particular calibration curves C can be used over a range of ambient

temperatures, for example at least $10^{\circ}C$ to $45^{\circ}C$.

The direction of the more tensile principal stress is given by the angle θ calculated from the angles of rotation at which induced voltages V_5 min occur. Angle θ is measured anticlockwise from axis X.

As an example calculation, supposed parameters for a railway wheel rim made of AAR grade C steel are as follows:

Calculated voltage V_5 diff = 60 μV,

Voltage V_6 (wheel) = 603 μV,

Voltage V_6 (air) = 654 μV,

Calculated angle $\theta = 85^{\circ}$.

By calculation, voltage $\Delta V_6 = 51$ which corresponds to a curve about midway between those for voltages $\Delta V_6 = 54$ and $\Delta V_6 = 49$ as in the graph of Fig. 8. The principal stress difference corresponding to a voltage V_5 diff value of 60 would be about 160 MPa (with an allowance for error).

Referring now to Fig. 9, an angle θ of 85° indicates the principal stresses, radial stress σ_r and circumferential stress σ_c, are at 85° and -5° to axis X, and that in the 85° direction, the difference between the principal stresses is tensile. Since 85° is very close to 90° (the radial direction) it can be deduced that radial stress σ_r is more tensile (or less compressive) than circumferential stress σ_c by about 160 MPa. The direction and relationship between these principal stresses σ_r and σ_c are shown in Fig. 9.

The instrument of the present invention provides a relatively simple procedure for non destructive measurement of stresses within magnetisable material. The instrument is particularly suitable for measuring stress within railway

wheels, although it will be appreciated that the instrument is suited to other applications.

It is anticipated that the instrument of the present invention will be relatively inexpensive to purchase and maintain, compared to previous equipment used for such meansurements.

Finally, it is to be appreciated that various modifications and/or alterations may be made to the instrument without department from the ambit of the present invention as defined in the claims depended hereto.

The claims defining the invention are as follows:

1. A probe for providing at least one parameter used in determining one or more stress characteristics within a surface layer of magnetisable material, including: a carrier rotatable about a rotation axis extending perpendicularly outwardly from a magnetisable material surface; an electromagnet mounted on the carrier and providing a pair of poles spaced apart, one on either side of the rotation axis, on a pole axis extending parallel to the material surface so that on carrier rotation the poles circulate about the rotation axis, the electromagnet being energisable to produce a magnetic field between the poles; a search coil fixed relative to the electromagnet between the poles, on an axis extending parallel to the material surface and perpendicular to the pole axis, so as to lie in the magnetic field; and, drive means operable to rotate the carrier to selected angular positions, the probe in use being positioned with the poles adjacent the material surface so that the magnetic field extends into the surface, shifts in the magnetic field caused by stress in the material surface inducing representative voltages in the search coil at the angular positions.

2. A probe as claimed in claim 1, wherein the drive means includes an electric drive motor having a rotary output shaft connected to the carrier for rotation thereof.

3. A probe as claimed in claim 2, wherein the drive motor is a stepper motor operable to rotate the carrier through small sequential angular increments to the selected angular positions.

4. A probe as claimed in any preceding claim, wherein the

electromagnet includes a C shaped magnet core having the poles at terminal ends thereof and an exciting coil wound about the core.

5. A probe as claimed in any preceding claim, wherein the search coil is a wire wound air cored coil positioned mid way between the poles.

6. A probe as claimed in any preceding claim, and further including at least one reference coil fixed relative to the electromagnet between the poles, on a respective axis extending parallel to the pole axis, so as to lie in the magnetic field, whereby in use of the probe the magnetic field produced between the poles induces voltages in the reference coil(s) representative of the magnetic field.

7. A probe as claimed in claim 6, wherein a pair of reference coils are provided one adjacent each end of the search coil and in a plane common with the search coil, the reference coils each being wire wound air cored coils.

8. A probe as claimed in any preceding claim, and further including a housing having an opening therein and a bearing surface adjacent the opening, the carrier being positioned in the housing with the poles and search coil exposed through the opening, the probe in use being positioned with the bearing surface abutting the material surface and the poles and search coil facing through the opening to the material surface.

9. A probe for providing at least one parameter used in determining one or more stress characteristics within a surface layer of magnetizable material, substantially as hereinbefore described with reference to what is shown in the accompanying drawings.

10. An instrument for determining one or more stress characteristics within a surface layer of magnetizable material, including: a probe as claimed in any preceding claim; and, control apparatus for controlling operation of the drive means rotating the carrier and, at each selected angular position of the carrier, for receiving the parameter(s) from the probe for determining the one or more stress characteristics.

11. An instrument as claimed in claim 10, wherein the control apparatus includes a power supply device for providing exciting power to the electromagnet.

12. An instrument as claimed in claim 11, wherein the supply device includes a fixed frequency and amplitude oscillator for generating sinusoidal alternating current power supply and a power amplifier for receiving the power supply from the oscillator and supplying the power to the electromagnet.

13. An instrument as claimed in any one of claims 10 to 12 wherein the control apparatus includes a signal process for processing induced voltages in the search coil.

14. An instrument as claimed in claim 13, wherein the signal processor includes one or more voltage filters.

15. An instrument as claimed in any one of claims 10 to 14, wherein the control apparatus includes a control computer for controlling operation of the drive motor and compiling voltage parameters from the search coil.

16. An instrument as claimed in any one of claims 10 to 15, wherein the control apparatus includes a display device for visually displaying the parameter values from the probe as derived values thereof.

17. An instrument for determining one or more stress characteristics within a surface layer of magnetizable material, substantially as hereinbefore described with reference to what is shown in the accompanying drawings.

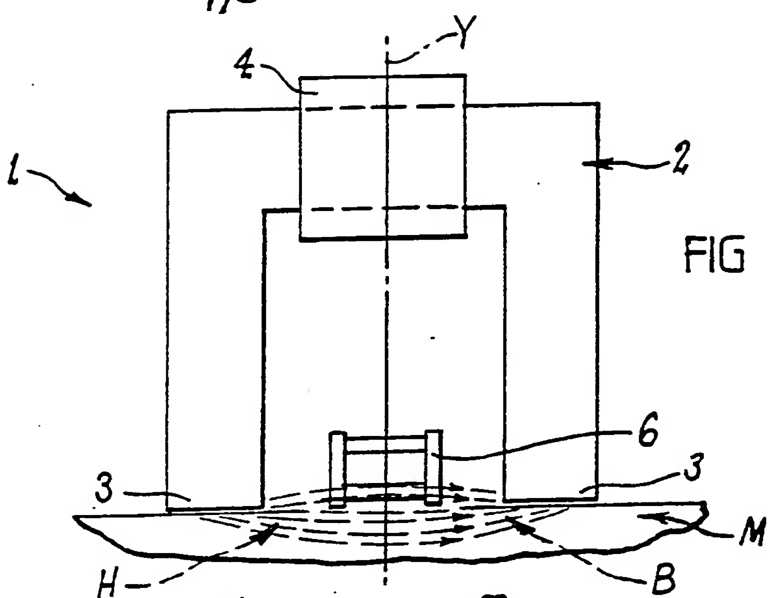

FIG 1

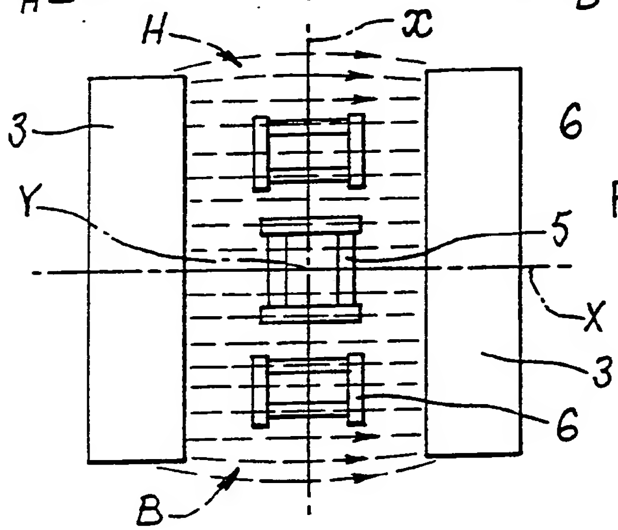

FIG 2

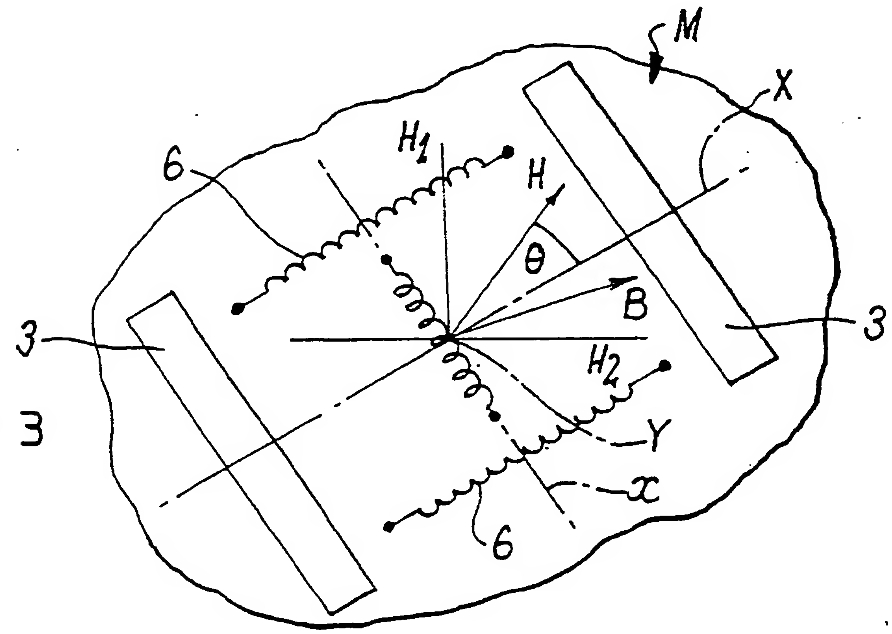

FIG 3

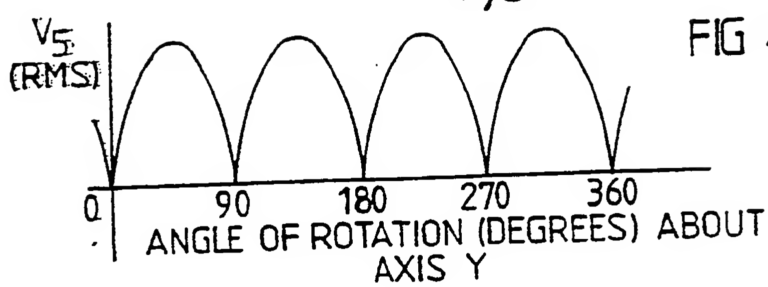

FIG 4

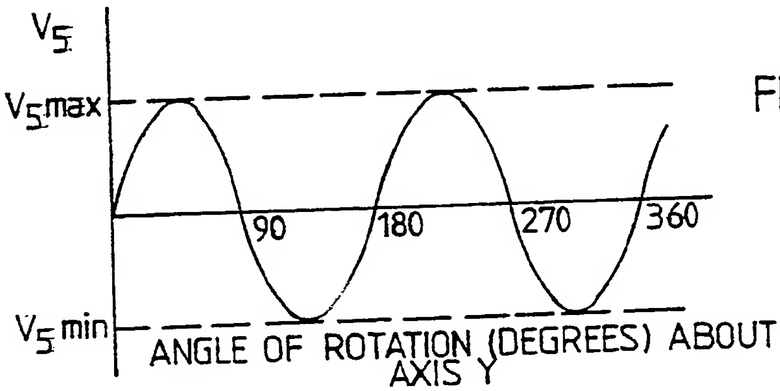

FIG 5

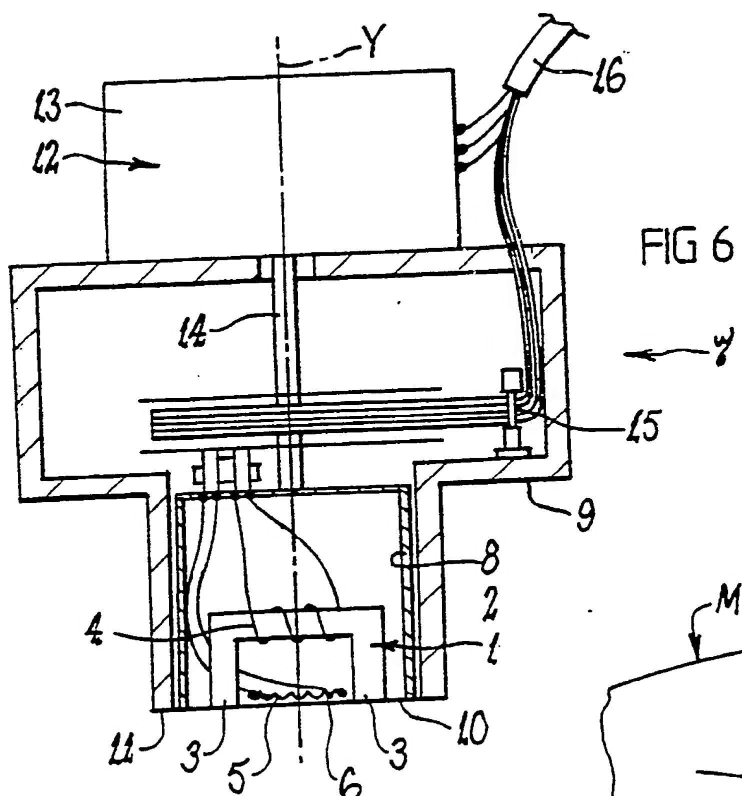

FIG 6

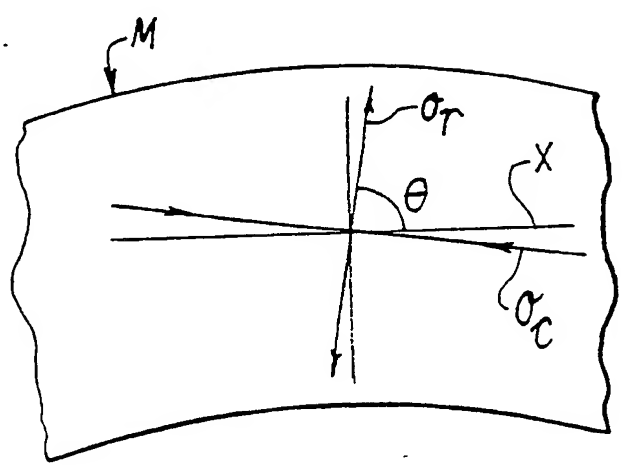

FIG 9

3/3

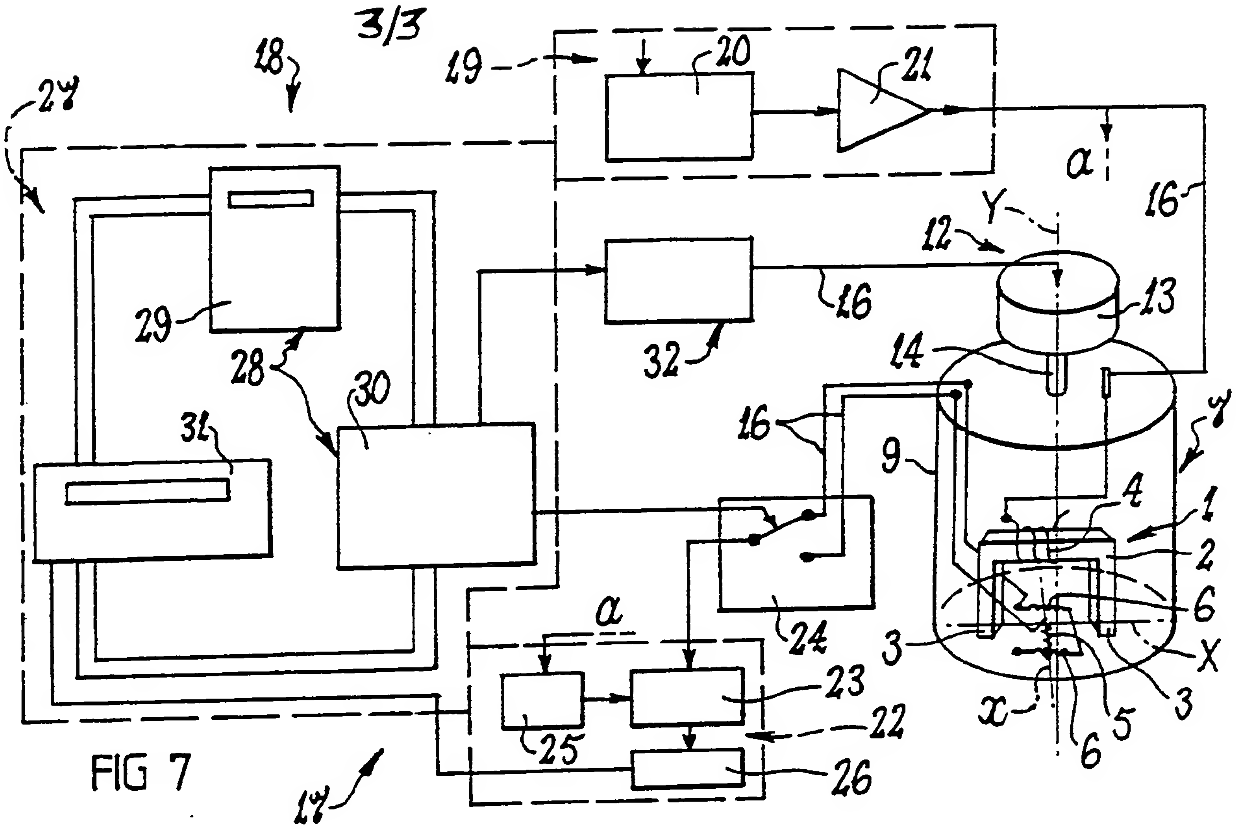
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FIG 7

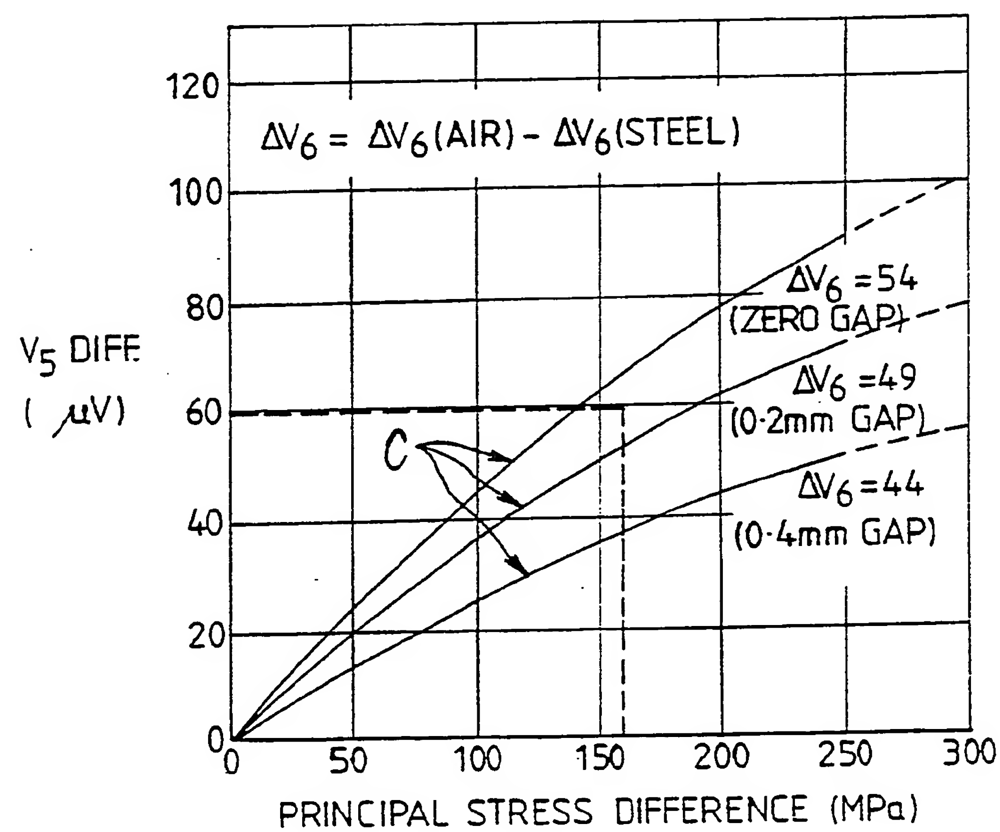
ΔV6 = ΔV6(AIR) - ΔV6(STEEL)
ΔV6 =54
(ZERO GAP)
ΔV6 =49
(0·2mm GAP)
ΔV6 =44
(0·4mm GAP)
C
V5 DIFF
(μV)
120
100
80
60
40
20
0
0
50
100
150
200
250
300
PRINCIPAL STRESS DIFFERENCE (MPa)

FIG 8

INTERNATIONAL SEARCH REPORT

International Application No PCT/AU 88/00293

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl.^{4} G01L 1/12, G01N 27/72

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC	G01L 1/12, G01N 27/72, 27/82, 27/83

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

AU :. IPC as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category [*]	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X	EP,A1, 18428 (MAGYAR TUDOMÁNYOS AKADÉMIA MŰSZAKI FIZIKAI KUTATO INTÉZET) 12 November 1980 (12.11.80)	(1-17)
X	Derwent Soviet Inventions Illustrated, Section II Electrical, Issued April 1969, D: Instruments, Control Computation p.68, SU 223432 (SHEVCHENKO, G.I.) 13 November 1968 (13.11.68)	(1)
A	US,A, 3798537 (DAHM) 19 March 1974 (19.03.74)	
A	FR,A1, 2378270 (INSTITUTE DE RECHERCHES DE LA SIDERURGIE FRANCAISE (IRSIO) 18 August 1978 (18.08.78)	
A	Patent Abstracts of Japan, P-50, page 69, JP,A, 54-62667 (SHIBAURA SEISAKUSHO K.K.) 3 December 1980 (03.12.80)	

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
17 November 1988 (17.11.88)	24 November 1988 (24.11.88)
International Searching Authority	**Signature of Authorized Officer**
Australian Patent Office	W.J. Major W.J. MAJOR

Form PCT/ISA/210 (second sheet) (January 1985)

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL APPLICATION NO. PCT/AU 88/00293

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report	Patent Family Members		
US 3798537	BE 760080 FR 2073752 AU 23275-70	CA 936236 NL 7017876	DE 2060725 ZA 7008355

END OF ANNEX